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(54) **REFRIGERATION STORAGE IN A REFRIGERANT VAPOR COMPRESSION SYSTEM**

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CPC . ***F25B 1/10*** (2013.01); ***F25B 9/008*** (2013.01); *F25B 2309/061* (2013.01); *F25B 2400/13* (2013.01); *F25B 2400/23* (2013.01); *F25B 2500/01* (2013.01)

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USPC 62/115, 186, 190, 222, 498, 500, 509; 165/253
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,213,633 A * 10/1965 Rosenstein et al. 62/535
4,176,529 A 12/1979 Stierlin et al.

(Continued)

FOREIGN PATENT DOCUMENTS

CN 1894548 A 1/2007
CN 101512255 A 8/2009

(Continued)

OTHER PUBLICATIONS

International Search Report mailed Nov. 28, 2011, 4 pgs.

(Continued)

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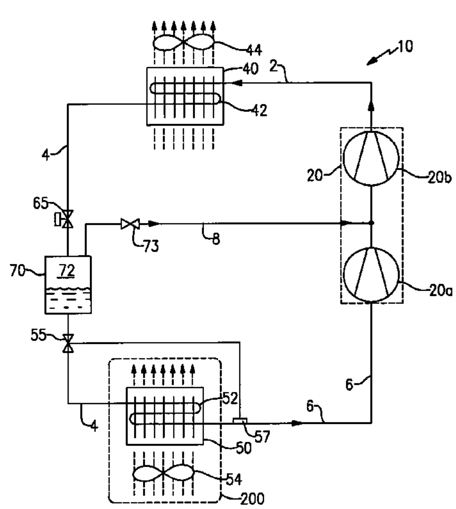
(57) **ABSTRACT**

A refrigerant vapor compression system (**10**) includes a plurality of components, including a flash tank (**70**), connected in a refrigerant flow circuit by a plurality of refrigerant lines (**2**, **4**, **6**, **8**). The system internal volume equals to the sum of the internal volumes of the plurality of components and the internal volume of the plurality of refrigerant lines. The internal volume of the flash tank ranges from at least 10% to about 30% of the total system internal volume.

19 Claims, 2 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

5,056,329	A	*	10/1991	Wilkinson	62/197
5,199,275	A		4/1993	Martin	
5,287,705	A		2/1994	Roehrich et al.	
5,320,167	A		6/1994	Johnson et al.	
5,331,824	A		7/1994	Miller et al.	
5,692,389	A	*	12/1997	Lord et al.	62/222
5,694,776	A		12/1997	Sahm	
5,730,216	A		3/1998	Viegas et al.	
5,848,537	A	*	12/1998	Biancardi et al.	62/324.6
5,946,928	A		9/1999	Wiggs	
6,385,980	B1		5/2002	Sienel	
6,460,352	B1		10/2002	Lemcoff et al.	
6,609,382	B2		8/2003	Vander Woude et al.	
6,708,510	B2		3/2004	Sulc et al.	
6,941,769	B1		9/2005	Hill, IV et al.	
7,089,751	B2		8/2006	Fleming, Jr. et al.	
7,096,679	B2	*	8/2006	Manole	62/115
7,231,776	B2		6/2007	Casar et al.	
7,451,617	B2		11/2008	Renz et al.	
2005/0132729	A1		6/2005	Manole	
2009/0250190	A1		10/2009	Siegenthaler	

FOREIGN PATENT DOCUMENTS

DE	10358428	A1	7/2007
EP	1990587		11/2008
WO	2007111594	A1	10/2007
WO	2007111595	A1	10/2007
WO	2008039204		4/2008
WO	2008054380	A2	5/2008
WO	2008130357	A1	10/2008
WO	2008130358	A1	10/2008
WO	2008140454	A1	11/2008
WO	2009082405	A1	7/2009
WO	2009091400		7/2009

OTHER PUBLICATIONS

Singapore Search Report and Written Opinion for International Application No. PCT/US2011/021685, Nov. 15, 2013, 17 pages.

International Preliminary Report on Patentability mailed Aug. 2, 2012.

European Office Action for application EP 11705063.3, dated Feb. 10, 2015, 6 pages.

* cited by examiner

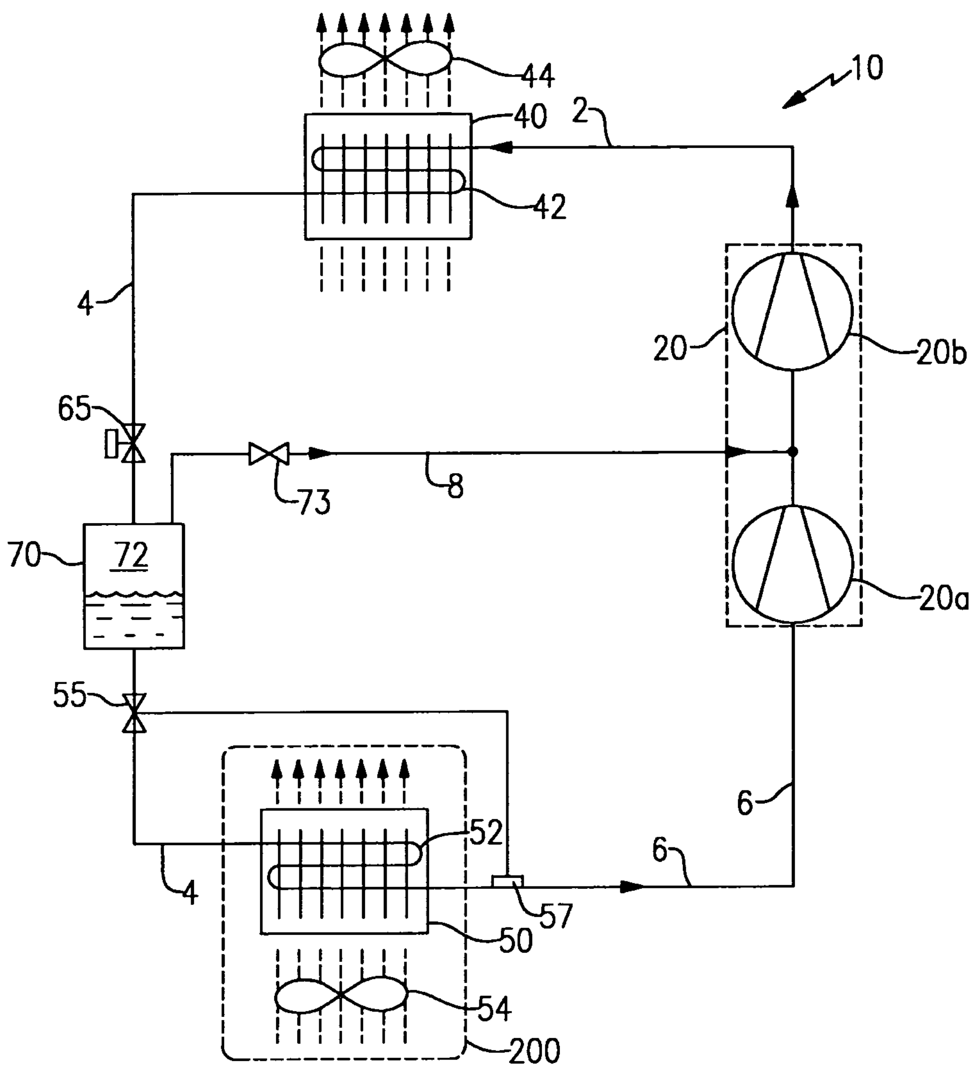


FIG.1

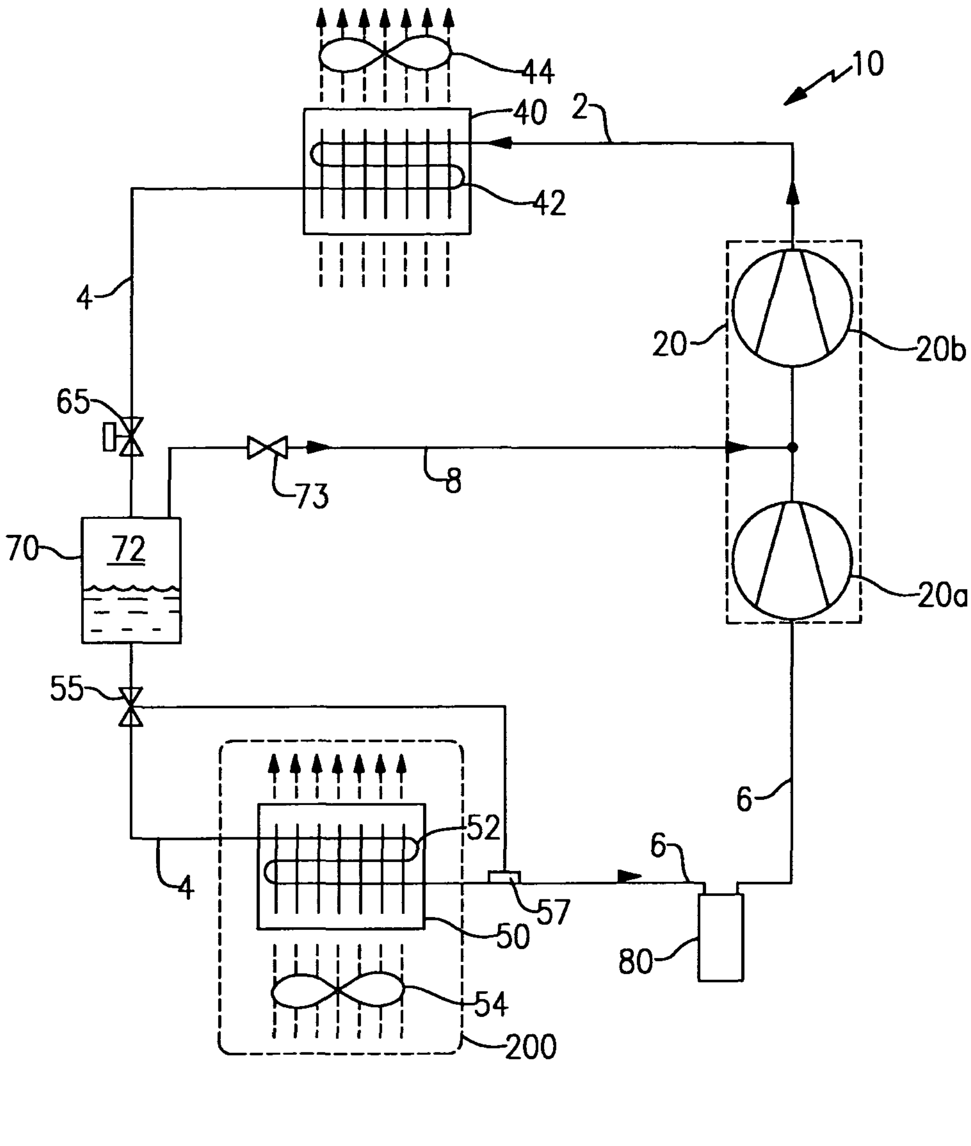


FIG.2

REFRIGERATION STORAGE IN A REFRIGERANT VAPOR COMPRESSION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to U.S. Provisional Patent Application Ser. No. 61/296,661 entitled "Refrigeration Storage in a Refrigerant Vapor Compression System" filed on Jan. 20, 2010. The content of this application is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

This invention relates generally to refrigerant vapor compression systems and, more particularly, to providing an adequate buffer volume for refrigerant storage in the refrigerant circuit of a refrigerant vapor compression system, most particularly, a refrigerant vapor compression system operating in a transcritical cycle with carbon dioxide as the refrigerant.

BACKGROUND OF THE INVENTION

Refrigerant vapor compression systems are well known in the art and commonly used for conditioning air to be supplied to a climate controlled comfort zone within a residence, office building, hospital, school, restaurant or other facility. Refrigerant vapor compression system are also commonly used in refrigerating air supplied to display cases, merchandisers, freezer cabinets, cold rooms or other perishable/frozen product storage areas in commercial establishments. Refrigerant vapor compression systems are also commonly used in transport refrigeration systems for refrigerating air supplied to a temperature controlled cargo space of a truck, trailer, container or the like for transporting perishable/frozen items by truck, rail, ship or intermodal. Refrigerant vapor compression systems used in connection with transport refrigeration systems are generally subject to more stringent operating conditions due to the wide range of operating load conditions and the wide range of outdoor ambient conditions over which the refrigerant vapor compression system must operate to maintain product within the cargo space at a desired temperature at which the particular product being stowed in the cargo space needs to be controlled can also vary over a wide range depending on the nature of cargo to be preserved.

The basic components of a refrigerant vapor compression system include a refrigerant compression device, a refrigerant heat rejection heat exchanger, and a refrigerant heat absorption heat exchanger, and an expansion device, commonly an expansion valve, disposed upstream, with respect to refrigerant flow, of the refrigerant heat absorption heat exchanger and downstream of the refrigerant heat rejection heat exchanger. These basic refrigerant system components are interconnected by refrigerant lines in a closed refrigerant circuit, arranged in a conventional manner in accord with a refrigerant vapor compression cycle. Such refrigerant vapor compression systems may be designed for and operated in a subcritical pressure range or in a transcritical pressure range depending upon the particular refrigerant with which the system is charged.

In refrigerant vapor compression systems operating in a subcritical cycle, the refrigerant heat rejection heat exchanger functions as a refrigerant vapor condenser. However, in refrigerant vapor compression systems operating in a transcritical cycle, the refrigerant heat rejection heat exchanger

functions as a refrigerant vapor cooler, commonly referred to as a gas cooler, rather than a condenser. Whether the refrigerant vapor compression system is operated in a subcritical cycle or in a transcritical cycle, the refrigerant heat absorption heat exchanger functions as a refrigerant evaporator. In operation in a subcritical cycle, both the condenser and the evaporator heat exchangers operate at refrigerant temperatures and pressures below the refrigerant's critical point. However, in refrigerant vapor compression systems operating in a transcritical cycle, the gas cooler operates at a refrigerant temperature and pressure in excess of the refrigerant's critical point, while the evaporator operates at a refrigerant temperature and pressure in the subcritical range. Thus, for a refrigerant vapor compression system operating in a transcritical cycle, the difference between the refrigerant pressure within the gas cooler and refrigerant pressure within the evaporator is characteristically substantially greater than the difference between the refrigerant pressure within the condenser and the refrigerant pressure within the evaporator for a refrigerant vapor compression system operating in a subcritical cycle.

As refrigerant vapor compression systems are often operated in applications having a wide range of refrigeration load demand, it is known to provide a buffer volume into the system refrigerant circuit in which excess refrigerant collects and is stored during low load demand operation or during system standstill between periods of operation. In refrigeration vapor compression systems operating in a subcritical cycle, the buffer volume for storing refrigerant may be typically provided by incorporating a receiver into the refrigerant circuit to receive liquid refrigerant from the condenser or by incorporating an accumulator into the refrigerant circuit between the evaporator and the suction inlet to the compression device. In refrigeration vapor compression systems operating in a transcritical critical cycle, the buffer volume for storing refrigerant would not be provided by a receiver because the refrigerant heat rejection heat exchanger operates as a gas cooler, not as a condenser, thus the refrigerant leaving the refrigerant heat rejection heat exchanger is in a vapor state, not a liquid state.

U.S. Pat. No. 7,024,883 discloses incorporating an accumulator in the refrigerant circuit of a refrigerant vapor compression system operable in a transcritical cycle wherein carbon dioxide refrigerant is stored while the system is inactive. The accumulator is designed to have an optimal size for preventing over-pressurization of the system when the refrigerant is at a maximum refrigerant temperature and a maximum refrigerant pressure reached when the system is inactive.

SUMMARY OF THE INVENTION

A refrigerant vapor compression system includes a plurality of components connected in a refrigerant flow circuit by a plurality of refrigerant lines. The components include at least a compression device, a refrigerant heat rejection heat exchanger, a refrigerant heat absorption heat exchanger, and a flash tank. Each of the components defines an internal volume and the plurality of refrigerant lines defines an internal volume. The system internal volume equals to the sum of the internal volumes of the plurality of components and the internal volume of the plurality of refrigerant lines. The internal volume of the flash tank ranges from at least 10% to about 30% of the system volume. In an embodiment of the refrigerant vapor compression system, the internal volume of the flash tank ranges from at about least 20% to about 30% of the system volume. In an embodiment, the internal volume of the flash tank ranges from at least 0.1 cubic feet up to about 0.2

cubic feet. In an embodiment, the internal volume of the flash tank is about 0.15 cubic feet. The flash tank may be disposed in the refrigerant flow circuit between the refrigerant heat rejection heat exchanger and the refrigerant heat absorption heat exchanger. The refrigerant vapor compression system may further include an economizer circuit operatively associated with the refrigerant flow circuit and including a refrigerant vapor injection line connecting the chamber of the flash tank in refrigerant vapor flow communication with an intermediate pressure stage of the compression device. In an embodiment of the refrigerant vapor compression system, the refrigerant is carbon dioxide.

In an aspect, a refrigerant vapor compression system is provided for a transport refrigeration unit for conditioning a cargo space. The refrigerant vapor compression system includes a compression device; a refrigerant heat rejection heat exchanger; at least one expansion device; a refrigerant heat absorption heat exchanger; a flash tank defining a chamber having an internal volume; and a plurality of refrigerant lines connecting the compression device, the refrigerant heat rejection heat exchanger, the at least one expansion device, the refrigerant heat absorption heat exchanger and the flash tank in a refrigerant flow circuit. The internal volume of the flash tank has a volume between at least 10% up to 30% of a total system internal volume. In an embodiment of the refrigerant vapor compression system the internal volume of the flash tank ranges from at about least 20% to about 30% of the system volume. In an embodiment, the internal volume of the flash tank ranges from at least 0.1 cubic feet up to about 0.2 cubic feet. In an embodiment, the internal volume of the charge storage device is about 0.15 cubic feet.

In an embodiment of the refrigerant vapor compression system, the flash tank is disposed in the refrigerant flow circuit between the refrigerant heat rejection heat exchanger and the refrigerant heat absorption heat exchanger, and the at least one expansion device includes a primary expansion device disposed in the refrigerant flow circuit between the flash tank and the refrigerant heat absorption heat exchanger and a secondary expansion device disposed in the refrigerant flow circuit between the refrigerant heat rejection heat exchanger and the flash tank. In conjunction with this embodiment, the plurality of refrigerant lines includes a refrigerant vapor injection line connecting the chamber of the flash tank to refrigerant vapor flow communication with an intermediate pressure stage of the compression device. In this embodiment, the flash tank also functions as an economizer.

In an embodiment, the refrigerant vapor compression system may further include a suction line accumulator interdisposed in the refrigerant flow circuit intermediate the refrigerant heat absorption heat exchanger and a suction inlet to the compression device, the suction line accumulator defining an internal volume, the sum of the internal volume of the flash tank and the internal volume of the suction line accumulator being up to 30% of the total system internal volume.

In an aspect, a method is provided for designing a refrigerant vapor compression system for operation in a transcritical cycle, the refrigerant vapor compression system having at least a compression device, a refrigerant heat rejection heat exchanger, at least one expansion device, and a refrigerant heat absorption heat exchanger connected in a refrigerant flow circuit by a plurality of refrigerant lines. The method includes the steps of: providing a flash tank interdisposed in the refrigerant flow circuit intermediate the refrigerant heat rejection heat exchanger and the refrigerant heat absorption heat exchanger; and sizing an internal volume of the flash tank to provide sufficient volume that at the maximum volume of liquid refrigerant collecting within the flash tank during operation, adequate volume is provided above the maximum liquid level within the flash tank to ensure that the process of separation of the refrigerant vapor and refrigerant liquid will still occur unimpeded. The method may also include the step of sizing the internal volume of the flash tank to have a volume between 10% up to 30% of the total internal volume of the refrigerant vapor compression system.

The total system internal volume may be determined by summing the respective internal volume of each of the plurality of components in the refrigerant flow circuit in which refrigerant may reside, including an internal volume of the compression device, an internal volume of the refrigerant heat rejection heat exchanger, an internal volume of the at least one expansion device, an internal volume of the refrigerant heat absorption heat exchanger, the internal volume of the flash tank, and the total internal volume of the refrigerant lines in the refrigerant flow circuit.

In an embodiment of the refrigerant vapor compression system, the refrigeration may be carbon dioxide and the refrigerant vapor compression system may be operated in a transcritical cycle.

BRIEF DESCRIPTION OF THE DRAWINGS

For a further understanding of the disclosure, reference will be made to the following detailed description which is to be read in connection with the accompanying drawing, where:

FIG. **1** is a schematic illustration of an exemplary embodiment of a refrigerant vapor compression system operable in a transcritical cycle and incorporating a flash tank in the refrigerant flow circuit; and

FIG. **2** is a schematic illustration of an exemplary embodiment of a refrigerant vapor compression system operable in a transcritical cycle and incorporating a flash tank and accumulator in the refrigerant flow circuit.

DETAILED DESCRIPTION

Referring now to FIGS. **1** and **2**, there are depicted therein exemplary embodiments of a refrigerant vapor compression system **10** suitable for use in a transport refrigeration unit for conditioning, that is at least cooling, but generally also dehumidifying, the air or other gaseous atmosphere within the temperature controlled cargo space **200** of a truck, trailer, container, intermodal container or like structure for transporting perishable/frozen goods. The refrigerant vapor compression system **10** is also suitable for use in conditioning air to be supplied to a climate controlled comfort zone within a residence, office building, hospital, school, restaurant or other facility. The refrigerant vapor compression system could also be employed in refrigerating air supplied to display cases, merchandisers, freezer cabinets, cold rooms or other perishable/frozen product storage areas in commercial establishments.

The refrigerant vapor compression system **10** is well suited for, and will described herein with respect to, operation in a transcritical cycle with a low critical temperature refrigerant, such as for example, but not limited to, carbon dioxide. However, it is to be understood that the refrigerant vapor compression system **10** may also be operated in a subcritical cycle with a higher critical temperature refrigerant such as conventional hydrochlorofluorocarbon and hydrofluorocarbon refrigerants. The refrigerant vapor compression system **10** includes a multi-step compression device **20**, a refrigerant heat rejection heat exchanger **40**, a refrigerant heat absorbing heat exchanger **50**, also referred to herein as an evaporator, and a primary expansion valve **55**, such as for example an electronic expansion valve or a thermostatic expansion valve, operatively associated with the evaporator **50**, with refrigerant lines **2**, **4** and **6** connecting the aforementioned components in a refrigerant flow circuit. Additionally, the refrigerant vapor compression system **10** of the invention includes a flash tank **70** interdisposed in refrigerant line **4** of the refrigerant flow circuit downstream with respect to refrigerant flow of the refrigerant heat rejection heat exchanger **40** and upstream with respect to refrigerant flow of the refrigerant heat absorption heat exchanger **50**. In the embodiment depicted in FIG. **2**, the refrigerant vapor compression system also includes a suction line accumulator **80** interdisposed in refrigerant line **6** of the refrigerant flow circuit intermediate the refrigerant outlet of the refrigerant heat absorption heat exchanger **50** and the suction inlet to the compression device **20**.

In a refrigerant vapor compression system operating in a transcritical cycle, the refrigerant heat rejection heat exchanger **40** constitutes a gas cooler through which supercritical refrigerant passes in heat exchange relationship with a cooling medium, such as for example, but not limited to ambient air or water, and may be also be referred to herein as a gas cooler, In a refrigerant vapor compression system operating in a subcritical cycle, the refrigerant heat rejection heat exchanger **40** would constitute a refrigerant condensing heat exchanger through which hot, high pressure refrigerant passes in heat exchange relationship with the cooling medium. In the depicted embodiments, the refrigerant heat rejection heat exchanger **40** includes a finned tube heat exchanger **42**, such as for example a fin and round tube heat exchange coil or a fin and mini-channel flat tube heat exchanger, through which the refrigerant passes in heat exchange relationship with ambient air being drawn through the finned tube heat exchanger **42** by the fan(s) **44** associated with the gas cooler **40**.

The refrigerant heat absorption heat exchanger **50** serves an evaporator wherein refrigerant liquid is passed in heat exchange relationship with a fluid to be cooled, most commonly air, drawn from and to be returned to a temperature controlled environment **200**, such as the cargo box of a refrigerated transport truck, trailer or container, or a display case, merchandiser, freezer cabinet, cold room or other perishable/frozen product storage area in a commercial establishment, or to a climate controlled comfort zone within a residence, office building, hospital, school, restaurant or other facility. In the depicted embodiments, the refrigerant heat absorbing heat exchanger **50** comprises a finned tube heat exchanger **52** through which refrigerant passes in heat exchange relationship with air drawn from and returned to the refrigerated cargo box **200** by the evaporator fan(s) **54** associated with the evaporator **50**. The finned tube heat exchanger **52** may comprise, for example, a fin and round tube heat exchange coil or a fin and mini-channel flat tube heat exchanger.

The compression device **20** functions to compress the refrigerant and to circulate refrigerant through the primary refrigerant circuit as will be discussed in further detail hereinafter. The compression device **20** may comprise a single multiple stage refrigerant compressor, such as for example a scroll compressor, a screw compressor or a reciprocating compressor, disposed in the primary refrigerant circuit and having a first compression stage **20***a* and a second compression stage **20***b*. The first and second compression stages are disposed in series refrigerant flow relationship with the refrigerant leaving the first compression stage passing directly to the second compression stage for further compression. Alternatively, the compression device **20** may comprise a pair of independent compressors **20***a* and **20***b*, connected in series refrigerant flow relationship in the primary refrigerant circuit via a refrigerant line connecting the discharge outlet port of the first compressor **20***a* in refrigerant flow communication with the suction inlet port of the second compressor **20***b*. In the independent compressor embodiment, the compressors **20***a* and **20***b* may be scroll compressors, screw compressors, reciprocating compressors, rotary compressors or any other type of compressor or a combination of any such compressors.

As noted briefly previously, the refrigerant vapor compression system **10** includes a flash tank **70** interdisposed in refrigerant line **4** of the primary refrigerant circuit downstream with respect to refrigerant flow of the gas cooler **40** and upstream with respect to refrigerant flow of the evaporator **50**. A secondary expansion device **65** is interdisposed in refrigerant line **4** in operative association with and upstream of the flash tank **70**. The secondary expansion device **65** may be an electronic expansion valve, such as depicted in FIGS. **1** and **2**, or a fixed orifice expansion device. Refrigerant traversing the secondary expansion device **65** is expanded to a lower pressure sufficient to establish a mixture of refrigerant in a vapor state and refrigerant in a liquid state. The flash tank **70** defines a chamber **72** wherein refrigerant in the liquid state collects in a lower portion of the chamber and refrigerant in the vapor state collects in the portion of the chamber **72** above the liquid refrigerant.

Liquid refrigerant collecting in the lower portion of the flash tank **70** passes therefrom through refrigerant line **4** and traverses the primary refrigerant circuit expansion device **55** interdisposed in refrigerant line **4** upstream with respect to refrigerant flow of the evaporator **50**. As this liquid refrigerant traverses the primary expansion device **55**, it expands to a lower pressure and temperature before entering enters the evaporator **50**. In traversing the evaporator **50**, the expanded refrigerant passes in heat exchange relationship with the air to be cooled, whereby the refrigerant is vaporized and typically superheated. As in conventional practice, the primary expansion device **55** meters the refrigerant flow through the refrigerant line **4** to maintain a desired level of superheat in the refrigerant vapor leaving the evaporator **50** to ensure that no liquid is present in the refrigerant leaving the evaporator. The low pressure refrigerant vapor leaving the evaporator **50** returns through refrigerant line **6** to the suction port of the first compression stage or first compressor **20***a* of the compression device **20** as depicted in FIG. **1**.

The refrigerant vapor compression system **10** also includes a refrigerant vapor injection line **18**. The refrigerant vapor injection line **18** establishes refrigerant flow communication between an upper portion of the chamber **72** of the flash tank **70** and an intermediate stage of the compression process. In the exemplary embodiment of the refrigerant vapor compression system **10** depicted in FIG. **1**, injection of refrigerant vapor into an intermediate pressure stage of the compression process would be accomplished by injection of the refrigerant vapor into the refrigerant passing from the first compression stage **20***a* into the second compression stage **20***b* of a single compressor or passing from the discharge outlet of the first compressor **20***a* to the suction inlet of the second compressor **20***b*. Thus, in cooperation, the flash tank **70**, the secondary expansion device **65** and the refrigerant vapor injection line **18** constitute an economizer circuit, with the flash tank **70** functioning as an economizer. The economizer circuit may also include a flow control valve **73** disposed in refrigerant vapor injection line **18** which may be selectively opened when the economizer circuit is called for to increase refrigeration capacity to meet refrigeration load demand and selectively closed when the economizer circuit is not needed to meet refrigeration load demand.

In the refrigerant vapor compression system **10**, the flash tank **70** has both an economizer function and a refrigerant charge storage function. That is, the chamber **72** serves both as a separation chamber in which refrigerant vapor and refrigerant liquid separated, as described hereinbefore, and also as a buffer reservoir in which refrigerant may collect and be stored during periods of operation and during periods when the system is inactive. With respect to refrigerant vapor compression systems utilized in transport refrigeration units, in particular, due to wide variation in refrigeration capacity demand typically imposed on the refrigerant vapor compression system, for example from high demand during a temperature drawdown mode to relatively low demand during a box temperature maintenance mode, a significant amount of the internal volume of the chamber **72** of flash tank **70** may be needed for liquid refrigerant storage during operation of the system. With the chamber **72** providing a buffer reservoir, it is not necessary to incorporate an accumulator into the refrigerant flow circuit. Rather, as in the embodiment of the refrigerant vapor compression system depicted in FIG. **1**, the flash tank **70** is sized with the internal volume defined by the chamber **72** providing sufficient volume that at the maximum volume of liquid refrigerant collecting within the chamber **72** during operation, adequate volume is provided above the maximum liquid level within the chamber **72** to ensure that the process of separation of the refrigerant vapor and refrigerant liquid will still occur unimpeded. Thus, in the refrigerant vapor compression system disclosed herein, the internal volume defined by the chamber **72** of the flash tank **70** is not sized simply to provide optimal refrigerant storage volume when the refrigerant vapor compression system is inactive.

In the refrigerant vapor compression system disclosed herein, the internal volume of the flash tank **70**, that is the internal volume defined by the chamber **72**, ranges between at least 10% up to 30% of a total system internal volume. In an embodiment of the refrigerant vapor compression system, the internal volume of the flash tank ranges from at about least 20% to about 30% of the total system internal volume. The total system internal volume equals the sum of the respective internal volumes of all the components and the refrigerant lines in the refrigerant flow circuit in which refrigerant may reside. In the refrigerant vapor compression system **10** depicted in FIG. **1**, the total system internal volume includes an internal volume of the compression device **20**, an internal volume of the refrigerant heat rejection heat exchanger **40**, a total internal volume of the two expansion devices **65** and **75**, an internal volume of the refrigerant heat absorption heat exchanger **50**, a total internal volume of the plurality of refrigerant lines **2**, **4**, **6**, **8**, and the internal volume of the flash tank **70**. For example, in an exemplary embodiment of a refrigerant vapor compression system for a transport refrigeration unit for conditioning a cargo space, the internal volume of the flash tank **70** may range from at least 0.1 cubic feet up to about 0.2 cubic feet. In an embodiment, the internal volume of the flash tank **70** may be about 0.15 cubic feet.

As noted previously, with the chamber **72** providing a buffer reservoir, it is not necessary to incorporate an accumulator into the refrigerant flow circuit. However, if desired, the refrigerant vapor compression system **10** may include a suction line accumulator **80** disposed in refrigerant line **6** between the refrigerant outlet of the evaporator **50**, i.e. the refrigerant heat absorption heat exchanger, and the suction inlet to the compression device **20**, as depicted in FIG. **2**. The suction line accumulator **80** defines an internal volume in which any liquid refrigerant in the refrigerant vapor flowing through refrigerant line **6** will be collected, thereby preventing the liquid refrigerant from passing on to the compression device **20**. Additionally, the internal volume of the suction line accumulator **80** provides a reservoir in which liquid refrigerant may collect and be stored during periods when the refrigerant vapor compression system **10** is inactive.

Thus, in the embodiment of the refrigerant vapor compression system **10** depicted in FIG. **2**, both the flash tank **70** and the suction line accumulator **80** define internal volumes which act as buffer reservoirs for storing refrigerant. Therefore, the sum of the internal volume of the flash tank **70** and the internal volume of the suction line accumulator **80** totals to adequate volume above the maximum liquid level within the chamber **72**, taking into consideration the internal volume of the suction line accumulator **80**, to ensure that the process of separation of the refrigerant vapor and refrigerant liquid will still occur unimpeded. In this embodiment, the sum of the internal volume of the flash tank **70** and the internal volume of the suction line accumulator **80** totals to a volume in the range of between at least 10% up to 30% of a total system internal volume. In the refrigerant vapor compression system **10** depicted in FIG. **2**, the total system internal volume includes an internal volume of the compression device **20**, an internal volume of the refrigerant heat rejection heat exchanger **40**, a total internal volume of the two expansion devices **65** and **75**, an internal volume of the refrigerant heat absorption heat exchanger **50**, a total internal volume of the plurality of refrigerant lines **2**, **4**, **6**, **8**, the internal volume of the flash tank **70**, and the internal volume of the suction line accumulator **80**.

While the present invention has been particularly shown and described with reference to the exemplary embodiments as illustrated in the drawing, it will be recognized by those skilled in the art that various modifications may be made without departing from the spirit and scope of the invention. For example, in an economized refrigerant vapor compression system wherein the economizing function is performed using a refrigerant-to-refrigerant heat exchanger, for example a brazed plate heat exchanger, instead of a flash tank, the internal volume of a suction line accumulator incorporated into the system should have an internal volume sized to provide a volume between 10% up to 30% of the total system internal volume to provide adequate volume for phase separation in addition to liquid refrigerant storage during operation.

The terminology used herein is for the purpose of description, not limitation. Specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as basis for teaching one skilled in the art to employ the present invention. Those skilled in the art will also recognize the equivalents that may be substituted for elements described with reference to the exemplary embodiments disclosed herein without departing from the scope of the present invention.

Therefore, it is intended that the present disclosure not be limited to the particular embodiment(s) disclosed as, but that the disclosure will include all embodiments falling within the scope of the appended claims.

I claim:

1. A refrigerant vapor compression system comprising a plurality of components connected in a refrigerant flow circuit by a plurality of refrigerant lines, said components including at least a compression device, a refrigerant heat rejection heat exchanger, a primary expansion device, a refrigerant heat absorption heat exchanger, and a flash tank;

each of said components defining an internal volume and the plurality of refrigerant lines defining an internal volume, the system volume equal to the sum of the internal volumes of said component volumes and the internal volume of the plurality of refrigerant lines, and the internal volume of the flash tank ranging from at least 10% to about 30% of the system volume;

wherein the flash tank is disposed in the refrigerant flow circuit between the refrigerant heat rejection heat exchanger and the refrigerant heat absorption heat exchanger.

2. The refrigerant vapor compression system as recited in claim **1** wherein the internal volume of the flash tank ranges from at about least 20% to about 30% of the system volume.

3. The refrigerant vapor compression system as recited in claim **1** wherein the internal volume of the flash tank ranges from at least 0.1 cubic feet up to about 0.2 cubic feet.

4. The refrigerant vapor compression system as recited in claim **3** wherein the internal volume of the flash tank is about 0.15 cubic feet.

5. The refrigerant vapor compression system as recited in claim **1** further comprising an economizer circuit operatively associated with the refrigerant flow circuit, the economizer including a refrigerant vapor injection line connecting the chamber of the flash tank in refrigerant vapor flow communication with an intermediate pressure stage of the compression device.

6. The refrigerant vapor compression system as recited in claim **1** wherein said refrigerant is carbon dioxide.

7. A refrigerant vapor compression system for a transport refrigeration unit for conditioning a cargo space, comprising:

a compression device;

a refrigerant heat rejection heat exchanger;

at least one expansion device;

a refrigerant heat absorption heat exchanger;

a flash tank defining a chamber having an internal volume; and

a plurality of refrigerant lines connecting the compression device, the refrigerant heat rejection heat exchanger, the at least one expansion device, the refrigerant heat absorption heat exchanger and the flash tank in a refrigerant flow circuit;

the internal volume of the flash tank having a volume between at least 10% up to 30% of a total system internal volume.

8. The refrigerant vapor compression system as recited in claim **7** wherein the internal volume of the flash tank ranges from at about least 20% to about 30% of the system volume.

9. The refrigerant vapor compression system as recited in claim **7** wherein the internal volume of the flash tank ranges from at least 0.1 cubic feet up to about 0.2 cubic feet.

10. The refrigerant vapor compression system as recited in claim **9** wherein the internal volume of the charge storage device is about 0.15 cubic feet.

11. The refrigerant vapor compression system as recited in claim **7** wherein said refrigerant is carbon dioxide.

12. The refrigerant vapor compression system as recited in claim **7** wherein the total system internal volume includes an internal volume of the compression device, an internal volume of the refrigerant heat rejection heat exchanger, an internal volume of the at least one expansion device, an internal volume of the refrigerant heat absorption heat exchanger, a total internal volume of the plurality of refrigerant lines and the internal volume of the flash tank.

13. The refrigerant vapor compression system as recited in claim **7** wherein the flash tank is disposed in the refrigerant flow circuit between the refrigerant heat rejection heat exchanger and the refrigerant heat absorption heat exchanger, and the at least one expansion device includes a primary expansion device disposed in the refrigerant flow circuit between the flash tank and the refrigerant heat absorption heat exchanger and a secondary expansion device disposed in the refrigerant flow circuit between the refrigerant heat rejection heat exchanger and the flash tank.

14. The refrigerant vapor compression system as recited in claim **13** wherein the plurality of refrigerant lines includes a refrigerant vapor injection line connecting the chamber of the flash tank to refrigerant vapor flow communication with an intermediate pressure stage of the compression device.

15. The refrigerant vapor compression system as recited in claim **14** further comprising a suction line accumulator interdisposed in the refrigerant flow circuit intermediate the refrigerant heat absorption heat exchanger and a suction inlet to the compression device, the suction line accumulator defining an internal volume, the sum of the internal volume of the flash tank and the internal volume of the suction line accumulator being up to 30% of the total system internal volume.

16. The refrigerant vapor compression system as recited in claim **7** wherein the refrigeration is carbon dioxide and the refrigerant vapor compression system is operable in a transcritical cycle.

17. A method for designing a refrigerant vapor compression system for operation in a transcritical cycle, the refrigerant vapor compression system having a plurality of components including at least a compression device, a refrigerant heat rejection heat exchanger, at least one expansion device, and a refrigerant heat absorption heat exchanger connected in a refrigerant flow circuit by a plurality of refrigerant lines, comprising:

providing a flash tank interdisposed in the refrigerant flow circuit intermediate the refrigerant heat rejection heat exchanger and the refrigerant heat absorption heat exchanger; and

sizing an internal volume of the flash tank to provide sufficient volume that at the maximum volume of liquid refrigerant collecting within the flash tank during operation, adequate volume is provided above the maximum liquid level within the flash tank to ensure that the process of separation of the refrigerant vapor and refrigerant liquid will still occur unimpeded.

18. The method as recited in claim **17** further comprising:

sizing the internal volume of the flash tank to have a volume between 10% up to 30% of the total internal volume of the refrigerant vapor compression system.

19. The method as recited in claim **18** further comprising determining the total system internal volume by summing the respective internal volume of each of said plurality of components in the refrigerant flow circuit in which refrigerant may reside and the total internal volume of the refrigerant lines in the refrigerant flow circuit.

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